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ORIGINAL RESEARCH

New mHealth hospital selection framework supporting decentralised telemedicine architecture for outpatient cardiovascular disease-based integrated techniques: Haversine-GPS and AHP-VIKOR

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Abstract

Cardiovascular diseases (CVDs) are conditions involving the heart or blood vessels which need specialised and urgent care. Centralised telemedicine is a client–server architecture fit for cardiovascular care, especially for monitoring health conditions, delivering healthcare services and providing other remote services by using mHealth. However, several challenges and unsolved issues remain, including (1) provision of healthcare services data in terms of hospital connectivity and continuous updates of all transactions occurring across distributed hospital networks for patient data, (2) lack of an accurate mHealth method to estimate time between patients with CVD and telemedicine hospitals for hospitalisation and (3) lack of investigation of important criteria for hospital evaluation. To develop a new mHealth framework for the evaluation and prioritisation of decentralised telemedicine hospitals based on integrated techniques Haversine-Global Positioning System (GPS) and analytical hierarchy process (AHP)-*VIseKriterijumska Optimizacija I Kompromisno Resenje* (VIKOR). The framework can serve all health emergency levels (i.e. risk, urgent and sick) of patients with CVD. Three methodology phases were developed. First is the identification of important decentralised hospital criteria which affect hospital evaluation to create a new dataset for this context. Second is the development of a new mHealth framework phase consequent of four development sequences: new integrated distance measurement through Haversine-based on GPS for time estimation for the convenient remote interaction with hospitals, combination for new hospital datasets and development of three decision matrixes based on a crossover of (1) healthcare service packages/time of arrival of patient at the hospital criteria and (2) lists of hospitals for evaluation and prioritisation using integration AHP-VIKOR techniques. Third is the objective validation of the constructed results. In addition, the proposed framework is evaluated by using a checklist benchmarking procedure. Experimental results reveal that the new mHealth framework is effective in decentralised telemedicine architecture and verify the ability of all connected hospitals. The new integrated distance measurement technique boosts the overall methodology of hospital evaluation and supports the combination of the new hospital datasets for prioritisation configuration. The proposed mHealth framework offers healthcare services for all emergence levels of patients with CVD through the blockchain concept and decision making theory. Objective validation reveals significant differences between the scores of groups, indicating that the ranking results are valid for the three decision matrices. Evaluation results show that the proposed mHealth framework exhibits an advantage over the benchmark frameworks with a percentage of 66.67% intersection with six comparison points highlighted by the academic literature.

Keywords mHealth · Hospital evaluation · Decentralised telemedicine · Cardiovascular · MCDM · Prioritisation · Blockchain

1 Introduction

The risk of diseases continuously emerges worldwide; for instance, cardiovascular diseases (CVDs) are the leading cause of death worldwide (Escobar-Curbelo and Franco-Moreno 2019; Moser et al. 2006). In Europe, CVDs are responsible for 3.9 million deaths (45% of deaths), with

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ischaemic heart disease, stroke and hypertension (leading to heart failure) being the major cause of CVD-related deaths (Sanz et al. 2020). Telemedicine plays an important role in diagnosing this disease by detecting the health conditions of patients, utilising the remote healthcare services of hospitals and so on (Albahri et al. 2020b, d; Mohammed et al. 2019a, b). Delivery of remote healthcare services for treatment improvement and disease prevention is essential, and telemedicine enables the provision of various healthcare services from hospitals (Albahri et al. 2018a, b, c, d; Napi et al. 2019; Shojanoori and Juric 2013; Shuwandy et al. 2020). Telemedicine is an information technology which allows patients to remotely consult hospitals for their medical concerns by utilising sensors attached to the patient's body, and mHealth methodologies such as smartphone applications offer new opportunities for CVD and health (Gagnon et al. 2009; Hussain et al. 2018; Mohammed et al. 2019a, b, 2020a, b Mohsin et al. 2018a, b; Salman et al. 2017; Shuwandy et al. 2019; Talal et al. 2019b; Yahyaie et al. 2019). The control and management of the load of healthcare services by the hospital selection approach can help minimise their limitations and offer continuous hospital support care for patients with CVD at remote sites in designated environments (Kalid et al. 2018). For a clear view of how hospital selection supports patients with CVD across telemedicine architecture, eight sequential questions are raised and answered as follows.

First question: '*What is the importance of hospital selection for patients with CVD?*'

Hospital selection has become increasingly competent at handling healthcare services in real-time, enabling fast diagnosis of illnesses, with suggestions and comparisons of treatments now being automated. Hospital selection is a suitable method to assign patients to appropriate hospitals and provide them with prompt and effective healthcare services (Natafgi et al. 2020). The main goal of hospital selection for patients with CVD is to improve and provide the needed services in time provided that many hospitals are available as alternatives (Albahri et al. 2019b). In these contexts, selection policy influences the enhancement ability of managing hospitals to attract patients and promote healthcare services in a suitable and timely manner. In addition, patients with critical health conditions can be transferred to an appropriate hospital remotely by using a comfortable telemedicine technology without endangering their life and routine screening. Thus, this approach can support patients with a distinct quality of care in a modern lifestyle and maintain their independence in a normal living environment. Two types of telemedicine architecture (i.e. centralised/decentralised) in the literature (Abugabah et al. 2020, Albahri et al. 2020a) are engaged with hospital selection to provide the needed healthcare services, as discussed while answering the second question.

Second question: *'What is architecture design of centralised/decentralised telemedicine for hospital connectivity?'*

The architecture of centralised telemedicine is categorised into three tiers: Tier 1 represents sensor-based, Tier 2 represents mHealth-based (Tier 1 and Tier 2 represent clients' side) and Tier 3 represents remote hospital (servers' side) (Albahri et al. 2019a). Hospital connectivity in centralised telemedicine architecture is managed and operated via medical centre (Tier 3) (Albahri et al. 2019a). Recently, the telemedicine architecture has adapted the blockchain technology to eliminate the third party in terms of authentication and produced a new version of decentralised telemedicine architecture (Mohsin et al. 2019a, b, c, 2020). Blockchain technology enhances Tier 3 operations (i.e. hospital connectivity) and maintains continuous updates of all transactions occurring across distributed hospital networks for patient data. In addition, the rapid growth of the mHealth strategy and the pressing need for effective healthcare services, especially for patients with CVD, is the power employment of decentralised telemedicine hospitals. In this line, the suitable hospital for patients with CVD can be selected, and the delivery of appropriate healthcare services within decentralised telemedicine hospitals can be controlled easily through mHealth. Figure 1 illustrates the diagram of both architectures.

As shown in Fig. 1, the hospital connectivity is achieved by centralised or decentralised telemedicine architecture in Tier 3. The offered healthcare services within each hospital are represented by three packages. On the other hand, the sensors at Tier 1 are attached to patients to send the vital signs of CVD to Tier 2, which is mHealth. Thus, the major process of mHealth faces two important actions represented by the offered healthcare services in each hospital and the time to reach the nearest one. For these connected hospitals in either centralised or decentralised architecture, the hospital evaluation and selection approach can be accomplished after achieving two preliminary strategies, as explained by answering the third question.

Third question: *'What are the two strategy steps before evaluating and selecting hospitals for patients with CVD?'*

The hospital selection approach for patients with CVD must be preceded by the following two-step strategy. Firstly, the triage emergency level for patients should be detected by using sensors in Tier 1 and then evaluating their vital signs by using mHealth in Tier 2. Triage comes from the French word 'trier' meaning 'to sort'. The concept was initially used to prioritise warfare systems for all casualties and give the necessary care to the most critically injured (Heidarzadeh et al. 2020). Three emergency levels can be detected through the triage strategy method: sick, urgent and risk (Kalid et al. 2018). Secondly, triaging is required to link with compatible healthcare service package to complete the processing of healthcare service provisions from the selected hospital.

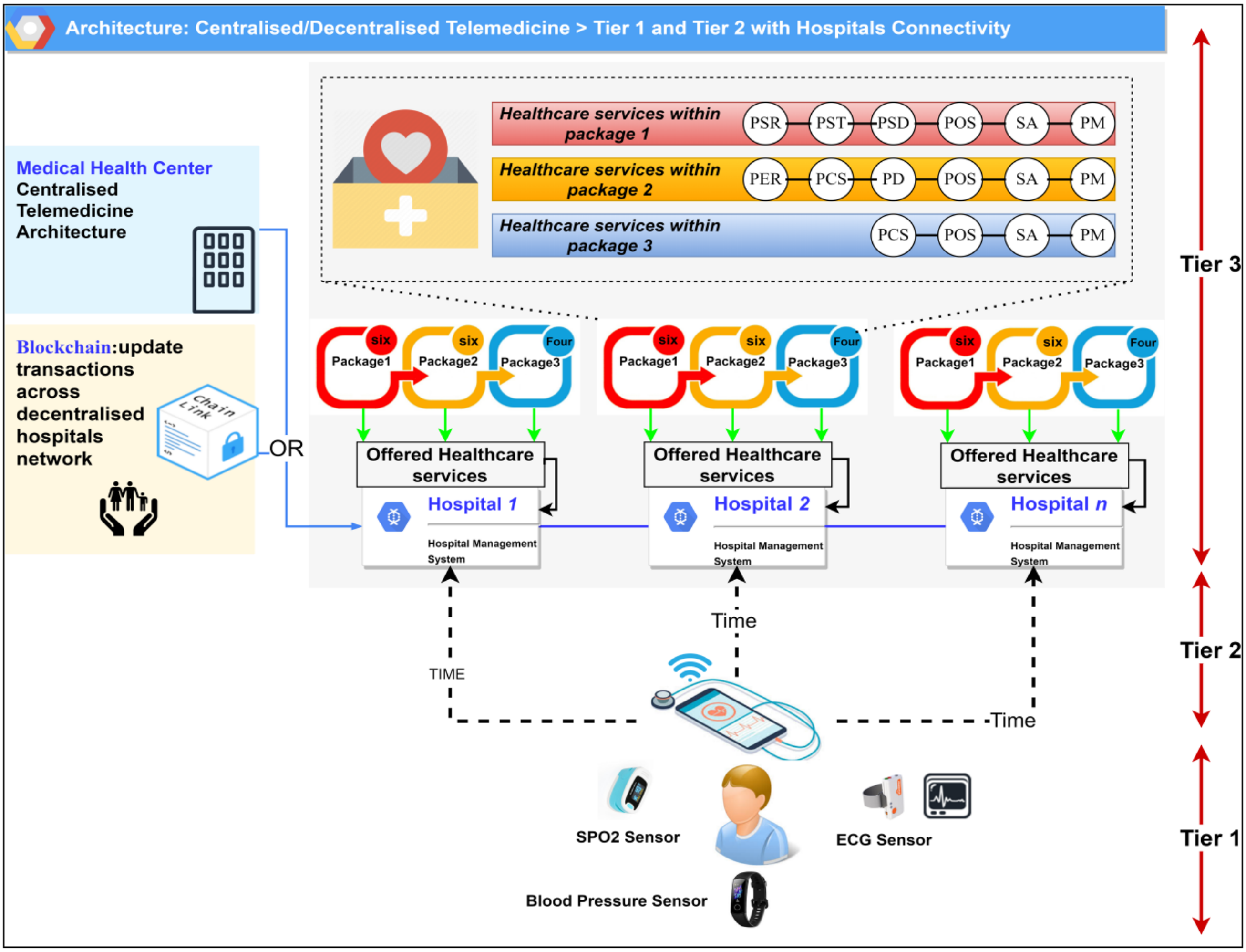

Fig. 1 Conceptual diagram for hospitals and patients in centralised/decentralised telemedicine

Three healthcare service packages are mentioned in the literature (i.e. package 1, package 2 and package 3) linked with the sick, urgent and risk levels, respectively (Albahri et al. 2018b). The three packages are specified for patients with CVD and can be provided within centralised/decentralised telemedicine hospitals. At this step, to establish the complete approach of hospital evaluation, the criteria to select the optimal hospital should be discussed by answering the next question.

Fourth question: *'Which criteria receive an increased importance in the hospital evaluation and selection for patients with CVD?'*

Accordingly, the understanding of the exact hospital criteria and their weights is important when selecting the appropriate one for critical patients. This research reviews the antecedents of hospital selection in centralised/decentralised telemedicine architecture utilising the important criteria of evaluation. The first criterion for hospital evaluation is the offered healthcare service packages in the hospitals. The most service number is offered in such a hospital. The most suitable is considered and can be selected, whereas the second criterion is the time of arrival of patient at the hospital (TAH), which is also reflected in the evaluation. TAH is an important factor in selecting the appropriate hospital, especially for patients with CVD (Albahri et al. 2019b). Many studies examined the potential impact of selective referral to hospitals on increased travel distance for patients living in urban and rural settings; they concluded that it increases the time to reach the hospital (Kovalchuk et al. 2018). The distance for patients to reach the nearest hospital varies significantly by region, and reconfiguration of emergency services could lead to patients with life-threatening conditions traveling long distances to the hospital (Kumar et al. 2015). In these contexts, the evaluation of suitability and efficacy of hospitals based on both criteria according to recent studies is important at this stage; accordingly, the answer to the fifth question will fill this gap.

Fifth question: '*What is the key direction of hospital selection based on identified criteria in centralised/decentralised telemedicine architecture?'*

A previous study (Albahri et al. 2019a) proposed a hospital selection methodology within the medical centre server for centralised telemedicine architecture. Telemedicine hospitals were evaluated through constructing a decision matrix (DM) based on the crossover of 'healthcare service packages' and 'hospital list' by using multi-criteria decision making (MCDM) methods. However, the selection process is dependent on the offered services in hospitals and ignores TAH. Patients with CVD and heart failures show the greatest association between distance and mortality (Di Castelnuovo et al. 2020). However, for urgent life-threatening conditions related to CVD, the resulting increased travel time to the hospital might adversely affect survival (Matthews et al. 2020). Therefore, patient location with respect to hospitals affects the healthcare system through their effect on the time to reach the nearest hospital. Prolonged time to reach the closest hospital increases deaths from heart attacks and unintentional injuries, and this finding is robust to several sensitivity checks, with evidence that seniors experience serious difficulty in accessing care. Another study in Albahri et al. (2019b) proposed a mHealth framework for hospital selection in centralised telemedicine architecture. The proposed DM was constructed based on the crossover of 'healthcare service packages/TAH' and 'hospital list' using MCDM. However, the study lacks to consider the number of services in the hospitals and depending on a single service (static rank) while making the decision by using the analytical hierarchy process (AHP) method. However, a critical point of the AHP is the inherently static nature of the decision, which means that the method is ineffective in the case of the future perpetration of medium-/long-term decision when we consider the data as dynamic number change (Improta et al. 2018). Thus, the ranking process for hospitals should be conducted towards a dynamic ranking approach because of infinite changes in the number of healthcare services in hospitals.

In addition, assumed values of TAH were provided without considering an accurate method for estimating the real-time states to provide real values of TAH. However, many points have not yet been achieved; accordingly, the answer to the sixth question will fill this gap.

Sixth question: '*What is the criticism and gap analysis for academic literature that attempts to develop a hospital selection approach for patients with CVD?*'

Despite the many benefits of centralised telemedicine, limitations exist in organising the risk management for the continuous provision of healthcare services during hospitalisation (Jin and Chen 2015; Sene et al. 2015). Various issues related to directions for further researches are discussed below:

Provision of healthcare services In general, healthcare services from centralised telemedicine hospitals discussed in Albahri et al. (2019a, b) are dependent on client–server architecture, where the provision of such services is a complex issue because of the many possible configurations of client/server environments and failure modes of client, server and network devices (Cineros and Lund 2017). Failure of centralised telemedicine architecture servers forms a critical integrity point in selecting and evaluating hospitals in terms of hospital connectivity and maintains continuous updates of all transactions occurring across distributed hospital networks for patient data. However, the risk of CVD disease in patients is greater than that of other diseases, and any disruption in providing healthcare services from hospitals can lead to link outage and even severe consequences (Hu et al. 2017; Woo et al. 2018). However, decentralised telemedicine architecture should be further investigated for the dynamic provision of healthcare services by providing updates on all transactions occurring across distributed hospital networks for patients with CVD.

Time estimation method for assigning patients to a hospital The actual traffic conditions related to the arrival times to the hospital and patient locations remain unclear (Albahri et al. 2019b). The distance measurement between patients and hospitals should be calculated first to estimate the real values of TAH to reach each hospital separately (Albahri et al. 2018b). Calculation of the time arrival to the nearest geo_tagged hospital is important. In reality, factors such as traffic jams, stopping points and transportation speed affect the time patients receive healthcare. These varying factors must be considered to determine arrival time. The augmented availability of huge geo_tagged datasets for scientific purposes also needs a proficient way to estimate the distance and TAH taken to transport patients to hospitals.

Hospital dataset and important criteria the last issue considered in this study is the lack of a clear approach for providing new hospital datasets based on identified criteria (i.e. healthcare service packages and TAH). Technically, the dataset aspects for both criteria should be presented within the same specific environment (i.e. city, country) to provide a precise evaluation and selection approach. However, only datasets on healthcare service packages concluding the three packages were mentioned in Albahri et al. (2019a) without TAH datasets between patients and telemedicine hospitals.

To the authors' knowledge, no study has provided a solution for hospital selection framework within decentralised telemedicine architecture that overcomes the challenges and issues above. However, the delivery of healthcare services to patients with CVD by using mHealth as a concept has not yet been issued in relation to the enumerated problems. Thus, a complete solution to all aforementioned challenges and issues is provided by answering the seventh question below.

Seventh question '*What are the recommend solution for such challenges and issues?* A complete solution is needed to overcome the challenges mentioned based on blockchain and decision-making techniques explained above.

Depending on the aforementioned, a new design in decentralised telemedicine architecture based on blockchain concepts can be adopted by developing a new integrated mHealth framework to evaluate and score the hospitals according to both important criteria. A flexible and efficient blockchain technology can be the bridge for the integration of hospitals for telemedicine system (Guo et al. 2019). In addition, the framework must be used to develop a new technique within mHealth based on GPS for calculating the distances and estimating the TAH values to provide a new dataset for hospital evaluation and selection. In addition, the mentioned challenges and issues can be overcome by utilising MCDM theory. The patients connect hospitals with two scenarios as shown in Fig. 2.

As shown in Fig. 2, a patient with CVD has two scenarios in selecting the appropriate hospital, and the offered healthcare services of hospitals play a key role in this selection. In both scenarios, the patient first sends the request to the nearest hospital. In the first scenario where the needed services are offered and the hospital sends a positive response, then the patient selects this hospital. In the second scenario where the needed services are not offered, a DM must be created to include all connected hospitals, excluding the nearest one, by utilising the blockchain availability benefits in updating DM data. Then, the suitable hospital is selected using MCDM-based updated DM. In these contexts, three DMs were proposed for the three emergency levels by applying an integrated method, namely, AHP and *VIseKriterijumska Optimizacija I Kompromisno Resenje* (VIKOR). Each DM can be constructed on the basis of the offered number of healthcare services and TAH values and hospital list to select the best one. The new framework adopted in decentralised telemedicine architecture with blockchain to avoid centralised problems and ensure the offering of health data provided by this technology. Such framework should be able to integrate the work process of hospital prioritisation simultaneously. Accordingly, the eighth question will come.

Eighth question '*What are the contribution, novelty and implication of the present study?'*

This study proposes a novel mHealth framework for hospital selection across decentralised telemedicine hospitals that meet the important hospitalisation criteria to assign patients with CVD to the appropriate hospital. The combination of new hospital datasets is presented for the first time, and the a new technique using Haversine-based GPS for distance measurement can be developed to estimate real TAH values. Thus, the integration amongst hospitals in decentralised telemedicine architecture for new evaluation and selection of the best one is necessary to help patients with CVD in the rapid delivery of healthcare services. The implication for the proposed mHealth framework can improve the balancing and scalability of healthcare services across telemedicine hospitals and provides continuous enhancements to enable physicians monitor their patients at any given time and geographical location (Yahyaie et al. 2019).

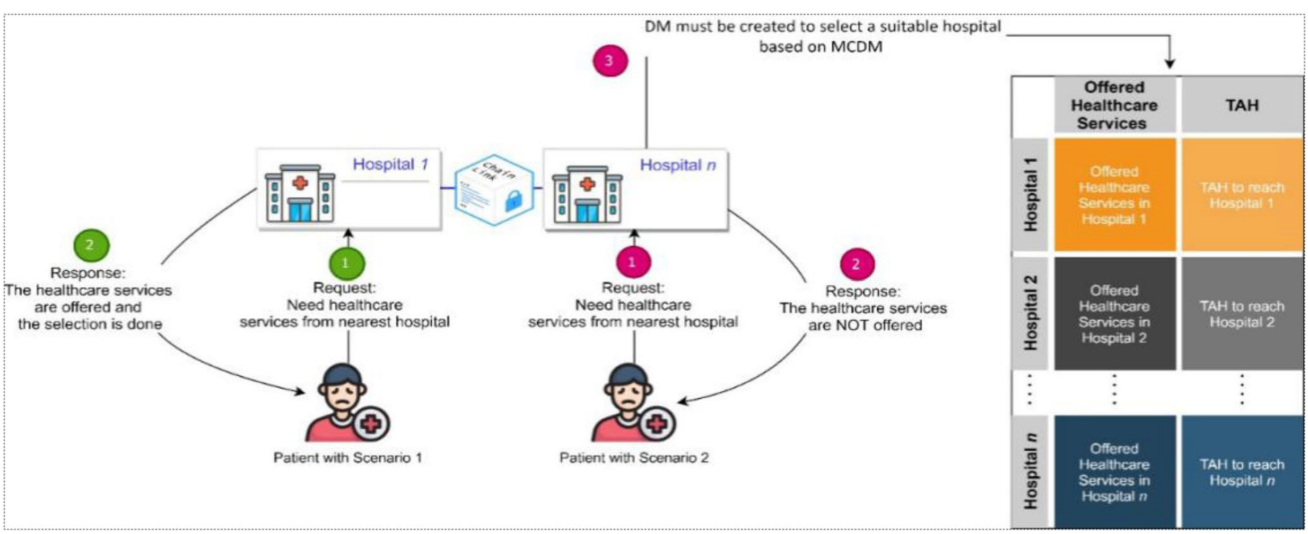

Fig. 2 Two scenarios of patients to select the appropriate hospital

2 Methodology

The development methodology of the presented study is divided into three sequence phases (i.e. identification of decentralised hospitals' criteria and dataset, development and presentation of the mHealth framework for prioritising decentralised hospitals including four stages and objective validation of the constructed results). As mentioned previously, two scenarios are possible when patients with CVD select appropriate hospitals (Fig. 2). The first scenario indicates that the selection can be achieved and does not need further step. However, the most urgent case can be found in the second scenario where the patient requires further connectivity steps with other hospitals. In this context, the presented methodology can handle the aforementioned case through an accurate selection technique as shown in the structure of the research methodology phases below (Fig. 3).

2.1 Phase 1: identification of decentralised hospital criteria and dataset

This phase handles the identification of two criteria that affect hospital prioritisation (i.e. healthcare service packages and TAH). The analysis for the new combined dataset related to both criteria is also presented.

2.1.1 Identification of healthcare service package criteria

Healthcare service packages are an important and attractive part that is utilised within decentralised telemedicine hospitals because of the required treatment process of patients with CHD (Mohammed et al. 2020a, b). Three packages, including various healthcare services, can be provided as quickly and accurately as possible to patients with CHD having the most urgent need based on their severity. The description of service type within the three packages is presented in Table 1.

The dataset of the above packages as the first criteria can be represented by the offered number of healthcare services in each package within hospitals (Albahri et al. 2019a). The suitable dataset for these packages can be utilised and adopted from a previous work (Albahri et al. 2019a). The dataset containing the real number of services was collected from 12 hospitals located in Baghdad, the capital city of the Republic of Iraq. In addition, the number of services is varied among the 12 hospitals, which can affect the prioritisation of the best among them.

2.1.2 Identification of TAH criteria towards decentralised hospital positions

The TAH criterion is an important factor for choosing an appropriate hospital (Albahri et al. 2018a, 2019b), especially for CHDs. TAH plays a key factor in patient life, and its importance is varied among the emergency levels of patients. For example, patients with a risk emergency level who need a short TAH to reach a specific hospital are more critical than patients with a sick emergency level who can wait (Sepehrvand et al. 2020). This situation could increase the risk of death. To give more sense to presented methodology and results, the TAH dataset is estimated within the same environment alongside with the package dataset from Baghdad City. The virtual patient location scenario should be identified on the map (Baghdad City) toward the same 12 hospitals, as shown in Fig. 4.

The identified patient location in Fig. 4 indicates that 12 TAH values exist between patient location towards the 12 hospitals and must be estimated as the second criteria. To end this, the estimation of the 12 TAH values can be attained after detecting the locations of patients and 12 hospitals and then computing the distances between the patient and 12 hospitals based on the detected positions. However, the distance of patients to reach the nearest hospital varies significantly by region, and the reconfiguration of emergency services could cause patients with life-threatening conditions to travel longer distances to the hospital. Therefore, a new technique should be developed based on the integration of an accurate formula (Haversine) and a GPS sensor to overcome such challenge (development phase). At this point, the two criteria are identified, and the datasets for prioritised decentralised hospitals based on the identified criteria are stated.

2.2 Phase 2: development of mHealth framework for prioritising decentralised hospitals

This phase includes a four-stage development process as illustrated in Fig. 5. The process can be achieved in mHealth connected with decentralised telemedicine hospital architecture as follows:

1. A new distance measurement technique is developed for detecting the longitude and latitude of patient and hospital positions based on the integrated Haversine formula and GPS sensor allocated within mHealth. The outcome of this technique is to compute the distances and estimate the 12 dataset values of TAH between the patient and the 12 hospitals.
2. The combination of healthcare service and TAH datasets should be analysed to introduce a new hospital dataset for hospital prioritisation. The new dataset is based on two criteria: healthcare service package data (number of services) and TAH for hospitals (12 values).

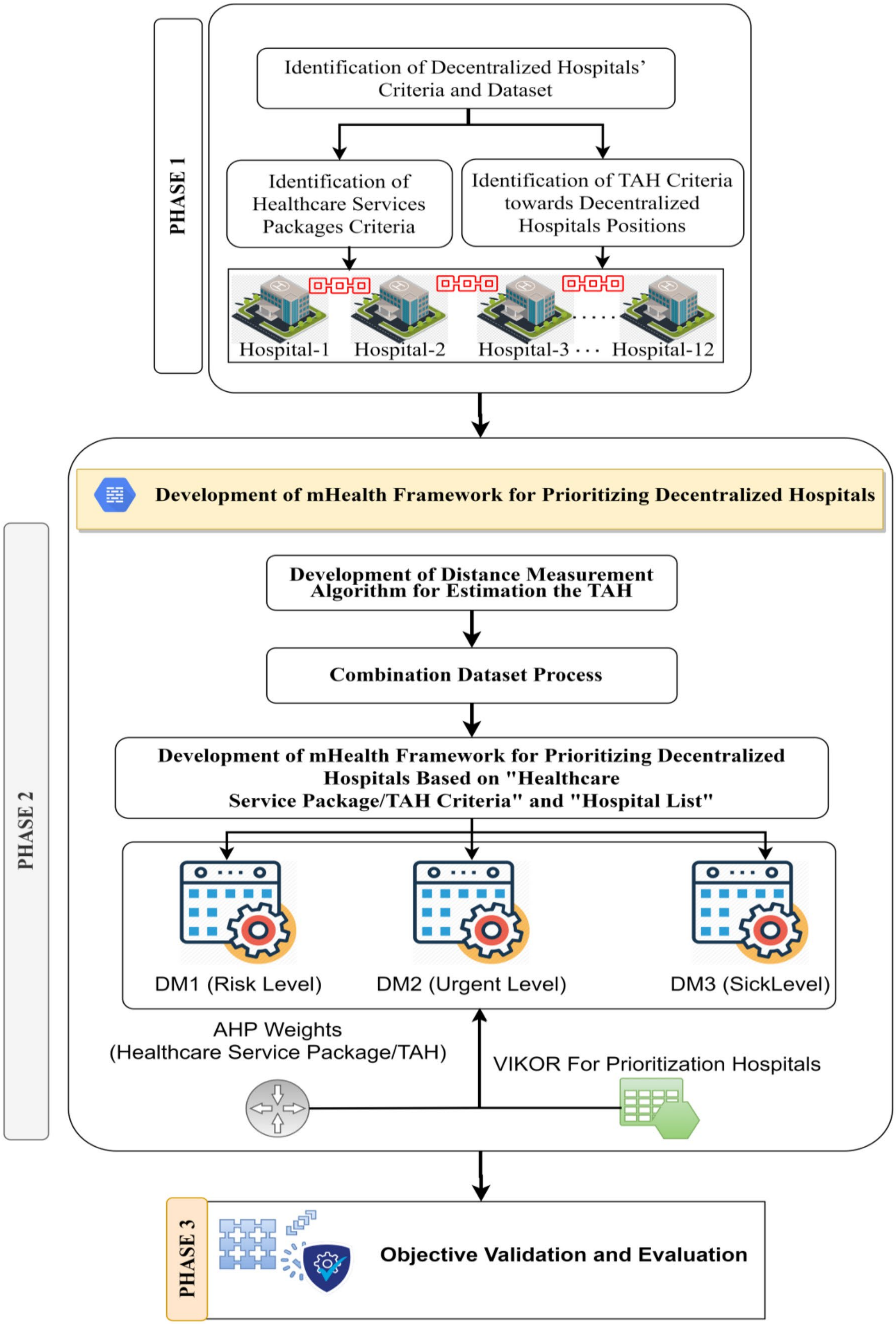

Fig. 3 Methodology phases for prioritising decentralised telemedicine hospitals based on mHealth

Table 1 Description of three healthcare service packages

Package	Included service	Package description
Package 1	PSR	Contains of six healthcare services and is provided for patients with risk level
	PST	
	PSD	
	POS	
	SA	
	PM	
Package 2	PER	Contains of six healthcare services and is provided for patients with urgent level
	PCS	
	PD	
	POS	
	SA	
	PM	
Package 3	PCS	Contains of four healthcare services and is provided for patients with sick level
	POS	
	SA	
	PM	

PSR prepare surgery room, *PST* prepare surgery team, *PD* prepare doctor, *POS* prepare O2 supplier, SA send ambulance, *PM* provide medications, *PER* prepare emergency room, *PCS* prepare consultant section

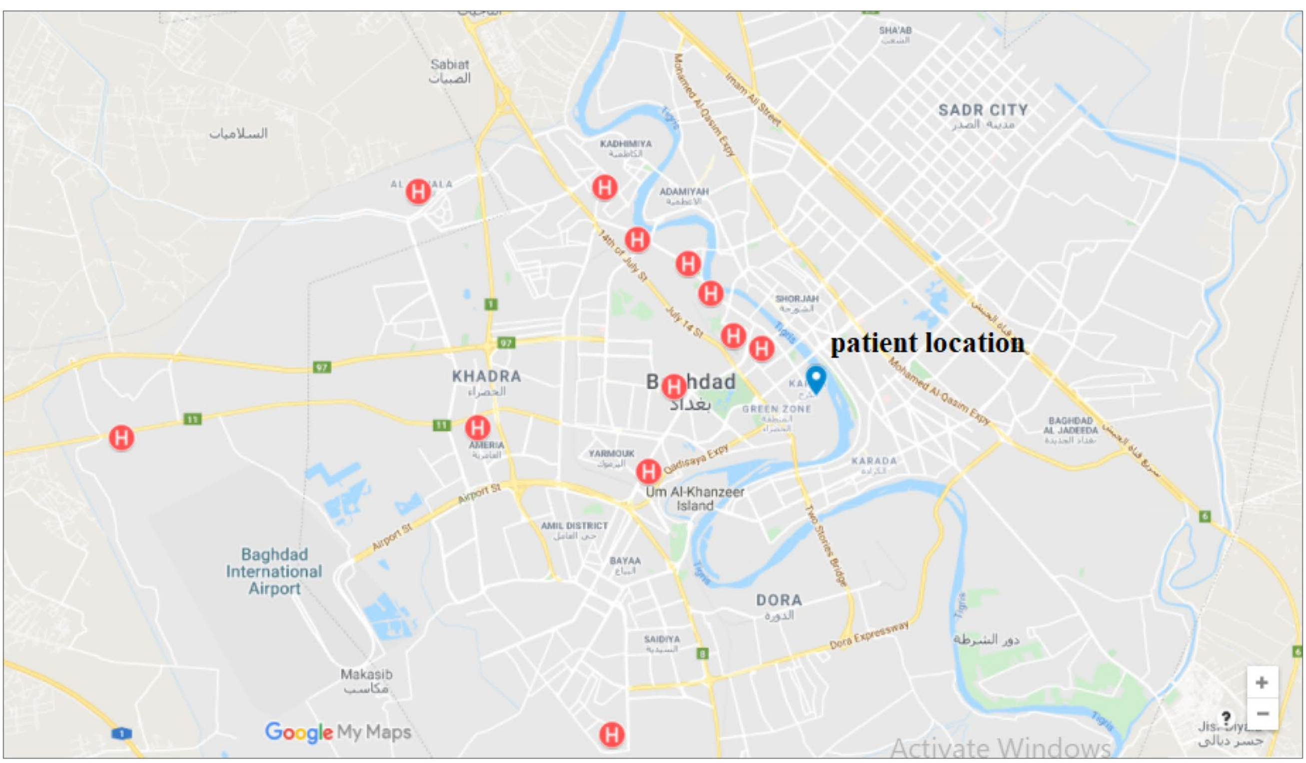

Fig. 4 Patient location scenario towards 12 hospital locations in Baghdad City

3. Three DMs for prioritisation of decentralised telemedicine hospitals are developed for patients with CHD to serve three emergency levels (i.e. risk, urgent and sick).
4. MCDM techniques are adaptive with the three developed DMs for handling the prioritisation configurations. In this stage, hospitals are evaluated and prioritised based on the combined dataset.

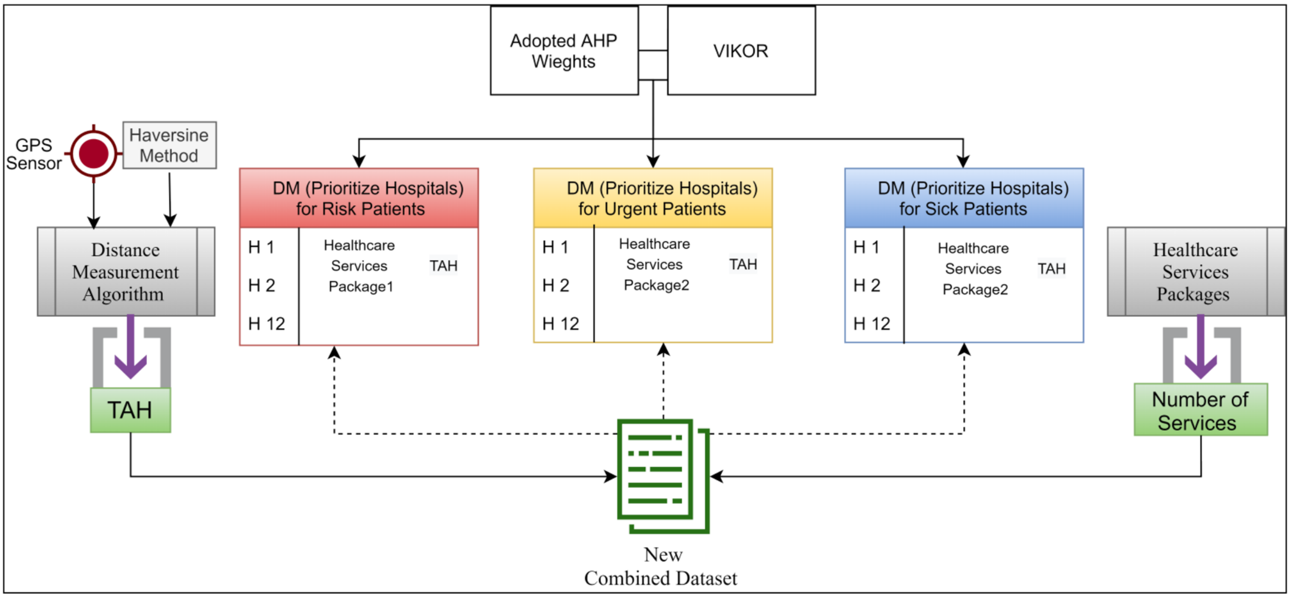

Fig. 5 mHealth framework stages

2.2.1 Development of integrated distance measurement technique for TAH estimation

This work adopted Haversine measurement to compute the distance between two points on the earth's surface using latitude and longitude as input variables. Haversine formula is important in navigation, giving great circle distance between two points on the surface of a sphere (Earth) by longitude and latitude (Cai et al. 2019). This formula is accurate enough for most calculations, but it neglects the effect of ellipsoidal, altitude hills and deep valleys on the earth's surface (Arifin et al. 2017). The distances should be calculated between patient position and all hospitals to find the TAH values for the identified virtual point (Fig. 4) using a GPS sensor. Then, the TAH must be calculated by assuming the average speed in Iraq ways by car equal to 60 km/h (as a proof of concept). Finally, the estimated stop point's time is added to TAH to increase accuracy in calculating the 12 values of TAH. The new technique for handling the above process alongside with the steps applied for calculating TAH is shown in Fig. 6. The outcome results of the developed technique are 13 positions (1 for patient and 12 for hospitals), with the 12 distances between patient and hospital positions alongside with 12 TAH values.

2.2.2 Combination dataset process

The dataset that affects hospital prioritisation results is divided into sub-datasets. The first dataset is the three healthcare service packages adopted from previous work (Albahri et al. 2019a). The second dataset is the TAH values resulting from the developed distance measurement technique after calculating the distance and time. Then, the combined output structure is utilised for both datasets to produce a new dataset to be used for the developed DMs of hospital prioritisation in the next section.

2.2.3 Development of three DMs for hospital prioritisation for three emergency levels

The outcome of this section is to develop three DMs for prioritising decentralised hospitals based on the crossover of (1) healthcare service package/TAH criteria and (2) hospital list. The DMs can prioritise 12 hospitals and select the best to serve patients with risk, urgent and sick emergency levels (Table 2).

For all DMs, (n) represents the number of services in the hospital, whereas (v) represents the value of TAH to reach the hospital. At this point, the three DMs are developed. However, in accordance with the presented recommended solution analyses for evaluation and prioritisation of hospitals in this study, the process will be achieved by utilising the integration of decision-making methods for considerable approach to reduce the problem complexity.

2.2.4 Integrated AHP weights and VIKOR method

The recommendation solution for our study is to use a MCDM method which deals with decision problems with respect to decision criteria. MCDM has the potential to contribute to a fair, transparent and rational priority-setting process (Abdullateef et al. 2016; Albahri et al. 2020f;

Fig. 6 Integrated distance measurement techniques to find the distances and TAH values between patient and all hospitals

Input	**Integrated Distance Measurement Technique: Find the TAH values between patient and hospital locations** **p(∅ , φ)=patient_ position (latitude, longitude) //from GPS,** **R = 6371 // radius of earth,** **h:no of hospitals**
Output	Set of TAH
Steps	1- I=1 2- While I< h do: 3- N=Hospital _ position (∅ , φ) //*Hospitals within Baghdad- AL Karkh* 4- Calculate Haversine _ distance: Distance (i)= $2\,R\sin^{-1}\left(\sqrt{sin^2\left(\frac{\emptyset p-\emptyset(N)}{2}\right)+cos(\emptyset i)cos(\emptyset j)sin^2\left(\frac{\varphi p-\varphi(N)}{2}\right)}\right)$ // ∅ and φ are correspondingly the latitudes and longitudes of points (p,N). 5- Calculate TAH(i) : 6- TAH(i)=distance(i)/speed //average speed in Iraq ways by car 7- TAH(i)=TAH+SP //sp=estimated time for stop points 8- I=i+1

Jumaah et al. 2018a, b; Rahmatullah et al. 2017; Talal et al. 2019a; Yas et al. 2017, 2018; Zaidan et al. 2015a, b, 2017a, b; Zaidan and Zaidan 2017, 2018). Nowadays, the priority matter is considered very challenges for different medical perspectives (Alamoodi et al. 2020a, b; Albahri et al. 2018a, b, c, d, 2020; Almahdi et al. 2019b; Alsalem et al. 2018; Enaizan et al. 2018; Martínez et al. 2015; Miao et al. 2020; Tinetti et al. 2019; Zaidan et al. 2018; Zughoul et al. 2018). A recently developed MCDM method is to combine two or more methods to recoup the weaknesses in a single method (Alao et al. 2020; Albahri et al. 2020c; Osamah Shihab Albahri et al. 2020; Jumaah et al. 2018a, b; Khatari 2019; Mohammed et al. 2020a, b; Salih et al. 2020; Tariq et al. 2018; Zaidan et al. 2019, 2020; Zughoul et al. 2020). AHP and VIKOR have become a commonly integrated MCDM method (Kaur et al. 2018; Rajak and Shaw 2019; Zaidan et al. 2015a, b). A description for MCDM methodology is presented below.

2.2.4.1 Adopt AHP weights for healthcare service packages and TAH criteria With respect to the criteria weights, a previous work (Albahri et al. 2019a) used the AHP method and constructed the weights for the healthcare service packages and TAH. Weighting was achieved by six cardiologists with more than 10 years of experience to provide an accurate weight for the both criteria considering the three emergency levels. The proper weights were set for three packages and related TAH on the basis of arithmetic mean as presented in Table 3.

2.2.4.2 VIKOR for prioritisation hospitals The VIKOR technique is utilised to rank the hospitals for the three DMs based on the weighted criteria from the AHP method. In general, evaluation criteria can be classified into two types: benefit and cost. The benefit criterion means that a larger value is more valuable whilst cost criteria are just the reverse. In this study, the healthcare service package is considered a benefit criterion, whereas TAH is considered a cost criterion. The available alternative scores (hospitals) should be ranked in ascending order. As a final point, the hospitals are ranked according to the number of offered services (n) and TAH values (v) from the best to the worst levels by using the VIKOR method. The best Q value provides an idea of which hospitals have higher numbers of offered services and a short TAH, which is expected to have the lowest Q value compared with others. The VIKOR steps are explained as follows (Albahri et al. 2020e; Almahdi et al. 2019a; Alsalem et al. 2019; Chang 2014; Opricovic and Tzeng 2004):

Step 1:

Determine the best f^*i and worst f^-i values of all criterion functions, $i = 1; 2; \ldots;$ n. If the ith function represents a benefit, then

$$\int_i^* = max_j \int ij, \int_i^- = min_j \int ij, \tag{1}$$

Step 2:

In this process, the weights for each criterion (AHP weights) are introduced to VIKOR. A set of weights $\mathrm{w} = \mathrm{w}_1, \mathrm{w}_2, \mathrm{w}_3, \cdots, \mathrm{w}_j, \cdots, \mathrm{w}_n$ from the decision-maker is accommodated in the DM; this set is equal to 1. The resulting matrix can also be calculated as illustrated in Eq. (2).

$$WM = wi * (f^*i - fij)/(f^*i - f^-i) \tag{2}$$

This process produces a weighted matrix as follows:

Table 2 Three DMs of hospital prioritisation for patient with risk, urgent and sick levels

DM1 (risk emergency level)

Criteria	Healthcare services package 1						TAH
Hospitals	PSR	PST	PSD	POS	SA	PM	
H1	PSR(*n*)-H1	PST(*n*)-H1	PSD(*n*)-H1	POS(*n*)-H1	SA(*n*)-H1	PM(*n*)-H1	TAH(*v*)-H1
H2	PSR(*n*)-H2	PST(*n*)-H2	PSD(*n*)-H2	POS(*n*)-H2	SA(*n*)-H2	PM(*n*)-H1	TAH(*v*)-H2
H3	PSR(*n*)-H3	PST(*n*)-H3	PSD(*n*)-H3	POS(*n*)-H3	SA(*n*)-H3	PM(*n*)-H1	TAH(*v*)-H3
H12	PSR(*n*)-H12	PST(*n*)-H12	PSD(*n*)-H12	POS(*n*)-H12	SA(*n*)-H12	PM(*n*)-H12	TAH(*v*)-H12

DM2 (urgent emergency level)

Criteria	Healthcare services package 2						TAH
Hospitals	PER	PCS	PD	POS	SA	PM	
H1	PER(*n*)-H1	PCS(*n*)-H1	PD(*n*)-H1	POS(*n*)-H1	SA(*n*)-H1	PM(*n*)-H1	TAH(*v*)-H1
H2	PER(*n*)-H2	PCS(*n*)-H2	PD(*n*)-H2	POS(*n*)-H2	SA(*n*)-H2	PM(*n*)-H1	TAH(*v*)-H2
H3	PER(*n*)-H3	PCS(*n*)-H3	PD(*n*)-H3	POS(*n*)-H3	SA(*n*)-H3	PM(*n*)-H1	TAH(*v*)-H3
H12	PER(*n*)-H12	PCS(*n*)-H12	PD(*n*)-H12	POS(*n*)-H12	SA(*n*)-H12	PM(*n*)-H12	TAH(*v*)-H12

DM3 (sick emergency level)

Criteria	Healthcare services package 3				TAH
Hospitals	PCS	POS	SA	PM	
H1	PCS(*n*)-H1	POS(*n*)-H1	SA(*n*)-H1	PM(*n*)-H1	TAH(*v*)-H1
H2	PCS(*n*)-H2	POS(*n*)-H2	SA(*n*)-H2	PM(*n*)-H1	TAH(*v*)-H2
H3	PCS(*n*)-H3	POS(*n*)-H3	SA(*n*)-H3	PM(*n*)-H1	TAH(*v*)-H3
H12	PCS(*n*)-H12	POS(*n*)-H12	SA(*n*)-H12	PM(*n*)-H12	TAH(*v*)-H12

$$\begin{bmatrix} w_1(f^*1-f11)/(f^*1-f^-1) & w_2(f^*2-f12)/(f^*2-f^-2) & \dots & w_i(f^*i-fij)/(f^*i-f^-i) \\ w_1(f^*1-f21)/(f^*1-f^-1) & w_2(f^*2-f22)/(f^*2-f^-2) & \dots & w_i(f^*i-fij)/(f^*i-f^-i) \\ \vdots & \vdots & \vdots & \vdots \\ w_1(f^*1-f31)/(f^*1-f^-1) & w_2(f^*2-f32)/(f^*2-f^-2) & \dots & w_i(f^*i-fij)/(f^*i-f^-i) \end{bmatrix} \tag{3}$$

Step 3:

Compute the values Sj and Rj, j = 1, 2, 3, …, J, i = 1, 2, 3, …, n by using the following equations:

$$Sj = \sum_{i=1}^{n} wi * (f^*i - fij)/(f^*i - f^-i), \tag{4}$$

$$Rj = \max_i wi * (f^*i - fij)/(f^*i - f^-i), \tag{5}$$

where *wi* are the weights of criteria expressing their relative importance.

Step 4:

Compute the values Qj, j = (1,2, ⋯ , J) by the following relation:

$$Q_j = \frac{v(S_j - S^*)}{S^- - S^*} + \frac{(1-v)(R_j - R^*)}{R^- - R^*}, \tag{6}$$

where.

$$S^* = \min_j S_j, S^- = \max_j S_j$$

$$R^* = \min_j R_j, R^- = \max_j R_j$$

v is the weight of the strategy of 'the majority of criteria' or 'the maximum group utility'); in this research, v is equal to 0.5.

Step 6

The set of alternatives (hospitals) can be ranked by sorting the value Q in ascending order. The lowest value of each hospital specifies high prioritisation.

2.3 Phase 3: objective validation and evaluation

This phase discusses in detail how the proposed framework can be validated and evaluated. The results are validated by utilising the objective validation in accordance with previously described methods (Kalid et al. 2018; Almahdi

Table 3 AHP Weights for three healthcare service packages and TAH (Albahri et al. 2019a)

Risk emergency level	Healthcare services package 1						TAH
	PSR	PST	PSD	POS	SA	PM	
	0.123	0.138	0.145	0.109	0.077	0.141	0.267
Urgent emergency level	Healthcare services package 2						TAH
	PER	PCS	PD	POS	SA	PM	
	0.115	0.099	0.138	0.107	0.085	0.088	0.368
Sick emergency level	Healthcare services package 3						TAH
	PCS	POS	SA	PM			
	0.12	0.134	0.231	0.168			0.347

et al. 2019a). The following steps were conducted for each ranking result (three DMs) to ensure that the results are statistically ranked:

1. The final prioritisation results are categorised into four equal groups. Each group contains three hospitals. However, the number of groups or the alternative number within each group does not affect the validation result (Abdulkareem et al. 2020a, b; Alaa et al. 2019).
2. The mean ± standard deviation (M ± STD) of each group is obtained on the basis of the normalisation of the hospital datasets (i.e. number of healthcare services and TAH values). The first group is statistically proven to be the highest amongst all other groups. The second group should be lower than or equal to the first group. The third group must be lower than the first and second groups or equal to the second group. The fourth group should be lower than the first, second and third groups or equal to the third group (Qader et al. 2017).

Equation (7) indicates the mean ($\bar{x}$) which represents the average as the sum of all the observed results from the sample divided by the total number (n):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i, \tag{7}$$

Equation (8) presents the measurement of the standard deviation to quantify the variation amount or dispersion of a set of data values.

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}. \tag{8}$$

In addition, the proposed framework is evaluated using a checklist benchmarking procedure as in studies (Albahri et al. 2019a; Ibrahim et al. 2019; Kalid et al. 2018). In this stage, the performance of the proposed framework is evaluated and compared with the relevant studies (Albahri et al. 2019a, b). In such a process, it is important to provide scenarios and checklist benchmarking that contains comparison points for evaluation of decentralised hospital selection framework according to various characteristics. Each scenario reflects issues that must be defined and addressed in hospital selection frameworks. Furthermore, these issues are considered points of comparison for the proposed framework. Checklist benchmarking provides a useful way to measure how effective the proposed work is compared with other works (Albahri et al. 2019a, b). The comparisons are done based on whether the compared works covered the issues addressed in the comparison scenario.

3 Results and discussion

This section presents the results of prioritising decentralised hospitals based on presented methodology phases. The results of the developed integrated distance measurement technique are obtained. Then, the new combined dataset structure is presented. The VIKOR configurations are applied to provide the ranks of the hospitals considering the obtained AHP weights of healthcare service package/TAH. Finally, the results of the objective validation are operated in the three emergency levels followed by the evaluation results using checklist benchmarking. The sequences of results are illustrated as follows.

3.1 TAH results based on integrated distance measurement technique

Firstly, patient location as identified previously on Fig. 4 is (33.31363, 44.405). The positions of the specified 12 hospitals are presented in Table 4. The table also shows the distances in km and TAH values (v) in minutes between the patient location and the 12 hospitals handled by the developed technique.

At this point, the THA values are obtained throughout the proposed technique presented in Fig. 6. These values will be used in the combination process in the next section to present a new dataset for decartelised telemedicine hospitals.

3.2 New combined dataset

In this section, the new combined dataset of two datasets is accomplished. The healthcare service package dataset (*n*) presented in Albahri et al. (2019a) is combined with the TAH dataset (TAH values) from Table 4 into a unified new dataset as presented in Table 5 below. At this point, the new dataset is equipped with required data to be utilised for the prioritisation process.

As shown in Table 5, the new dataset contains on two main important criteria that affect the prioritisation process of hospital selection. The evaluation and prioritisation of the 12 hospitals are achieved based on the new healthcare service numbering data together with the TAH value data in Table 5 as shown in the results of the next section.

3.3 Prioritisation results

In this stage, the results of AHP-VIKOR for prioritisation of three DMs of the three emergency levels are shown in Table 6.

For all ranks, the prioritisation processes for the 12 hospitals are stated. The principal results of the hospital evaluation and prioritisation satisfy the mentioned challenges. The use of the VIKOR method for prioritisation of hospitals can rapidly identify the most suitable option based on the adopted AHP weights. Thus, the 12 hospitals are ranked according to the ascending order of Q values, and low values indicate optimal performance. In these contexts, a hospital that is near the high record are the best record (i.e. the hospital that gain order 1) is suitable and must be given the highest priority level. The ascending order states the new evaluation approach to select the best hospital (i.e. hospital that has a good level of offered services and short TAH).

3.4 Validation and evaluation results

In this section, and as explained in phase 3, the proposed framework validation and evaluation are presented in detail as follows:

3.4.1 Objective validation results

The objective validation can be constructed by dividing the prioritisation results for hospitals into four equal groups. Each group comprises three hospitals. Mean ± SD is calculated for each group based on the normalisation scores generated by the VIKOR process to ensure that the prioritised hospitals undergo systematic ranking (see Table 7).

Initial observation of the ranking results of the four hospitals groups shows that the groups are systematically distributed as the ranking results of the second group starting from the end of the ranking results of the first group and so on for other groups. Statistical analysis is performed among the hospitals groups, and Eqs. (7) and (8) are applied to obtain the M ± STD for the three DM as shown in Table 7. For DM1, the first group has M ± STD = 0.1011 ± 0. The first group is the highest-scoring among the four groups. The second group has M ± STD = 0.0947 ± 0, which is lower than that of the first group but higher than those of the third and fourth groups. The third group has M ± STD = 0.07867 ± 0.01781, which is lower than those of the first, second and third groups but higher than that of the fourth group. The fourth group has M ± STD = 0.09233 ± 0.00557, which is the lowest among the four groups. For DM2, the first group has M ± STD = 0.0897 ± 0.0196, which is the highest among the four groups. The second group has M ± STD = 0.0854 ± 0.0196, which is lower than that of the first group but higher than those of the third and fourth groups. The third group has M ± STD = 0.0854 ± 0.0196, which is lower than those of the first, second and third groups but higher than that of the fourth group. The fourth group has M ± STD = 0.0785 ± 0.0117, which is the lowest among the four groups. Finally, for DM3, the first group has M ± STD = 0.1282 ± 0, whereas the second group has M ± STD = 0.1188 ± 0. The third group has M = 0.1177 ± 0.021, which is lower than those of the first, second and third groups but higher than that of the fourth

Table 4 Hospitals positions, distance measurements and TAH values between patient location and 12 hospitals

Hospital	Position	Distance measurement (km)	TAH value (min)
H1	33.330505, 44.379777	3.002212	18.00221
H2	33.294077, 44.352315	5.357234	20.35723
H3	33.069445, 44.364408	27.41364	42.41364
H4	33.327219, 44.388631	2.143938	17.14394
H5	33.370645, 44.338045	8.881258	23.88126
H6	33.369388, 44.277508	13.3679	28.3679
H7	33.350338, 44.364818	5.531396	20.5314
H8	33.347894, 44.375055	4.717599	19.7176
H9	33.316835, 44.360495	4.150796	19.1508
H10	33.347878, 44.374331	4.75615	19.75615
H11	33.362285, 44.352838	7.262993	22.26299
H12	33.303046, 44.181359	3.002212	35.81598

group. The fourth group has M ± STD = 0.1073 ± 0.0056, which is the lowest scores among the four groups. Overall, the statistical results for hospitals indicate that the ranking results underwent systematic ranking and valid.

3.4.2 Evaluation results

Several important points (checklist benchmarking) are compared according to the direction of the presented topic for

Table 5 New combined dataset for three healthcare service packages and TAH values in 12 hospitals

Hospital	Package 1: healthcare service data						TAH value
	PSR	PST	PSD	POS	SA	PM	
H1	14	23	2	28	5	100	18.00221
H2	10	45	3	20	6	90	20.35723
H3	5	28	5	10	4	75	42.41364
H4	6	40	6	11	5	95	17.14394
H5	12	30	4	25	7	150	23.88126
H6	9	36	2	20	3	110	28.3679
H7	4	29	3	10	4	45	20.5314
H8	7	42	2	17	5	80	19.7176
H9	3	45	2	8	4	50	19.1508
H10	5	33	1	13	3	60	19.75615
H11	5	19	2	14	8	40	22.26299
H12	7	24	2	18	4	125	35.81598

Hospital	Package 2: healthcare service data						TAH value
	PER	PCS	PD	POS	SA	PM	
H1	36	10	25	41	3	75	18.00221
H2	25	8	12	30	4	65	20.35723
H3	15	6	17	20	2	45	42.41364
H4	18	8	10	23	3	50	17.14394
H5	21	10	18	25	4	80	23.88126
H6	30	12	20	35	1	70	28.3679
H7	28	9	15	33	2	30	20.5314
H8	13	7	17	22	3	50	19.7176
H9	10	14	23	15	2	35	19.1508
H10	35	11	25	40	2	40	19.75615
H11	20	9	19	25	6	90	22.26299

Hospital	Package 3: healthcare service data				TAH value
	PCS	POS	SA	PM	
H1	5	20	1	25	18.00221
H2	3	15	2	30	20.35723
H3	2	10	1	25	42.41364
H4	3	11	2	25	17.14394
H5	5	13	2	40	23.88126
H6	6	17	1	35	28.3679
H7	4	20	2	15	20.5314
H8	3	10	3	25	19.7176
H9	7	8	2	15	19.1508
H10	6	20	2	20	19.75615
H11	4	14	3	40	22.26299
H12	8	16	2	35	35.81598

Table 6 Three DMs results

DM1 prioritisation results				
Hospital ranking	S	R	Q	Order
H2	0.283	0.087	0	1
H9	0.399	0.093	0.166	2
H11	0.352	0.16	0.264	3
H1	0.45	0.117	0.289	4
H8	0.486	0.116	0.334	5
H4	0.578	0.128	0.482	6
H5	0.612	0.141	0.558	7
H7	0.625	0.135	0.56	8
H6	0.565	0.174	0.575	9
H10	0.717	0.145	0.704	10
H3	0.656	0.18	0.708	11
H12	0.721	0.267	1	12
DM2 prioritisation results				
Hospital ranking	S	R	Q	Order
H11	0.313	0.071	0.047	1
H 1	0.275	0.147	0.11	2
H2	0.361	0.12	0.178	3
H7	0.447	0.092	0.244	4
H8	0.455	0.115	0.288	5
H10	0.378	0.184	0.291	6
H9	0.562	0.11	0.414	7
H4	0.58	0.138	0.476	8
H6	0.484	0.239	0.503	9
H5	0.521	0.221	0.523	10
H3	0.734	0.248	0.827	11
H12	0.693	0.368	0.949	12
DM3 prioritisation results				
Hospital ranking	S	R	Q	Order
H11	0.199	0.08	0	1
H2	0.339	0.116	0.194	2
H7	0.417	0.112	0.266	3
H8	0.424	0.168	0.357	4
H4	0.512	0.116	0.367	5
H10	0.463	0.174	0.405	6
H9	0.49	0.168	0.423	7
H5	0.462	0.208	0.455	8
H1	0.531	0.231	0.559	9
H6	0.564	0.231	0.592	10
H12	0.541	0.347	0.743	11
H3	0.798	0.234	0.831	12

the telemedicine environment. Checklist benchmarking is a useful way to measure the effectiveness of the proposed work is compared with other methods. The following points are illustrated to demonstrate the comparison in the checklist benchmarking as presented in Table 8.

- *1st point: decentralised telemedicine architecture* This point presents whether or not the presented framework supports decentralised architecture within the telemedicine environment. The blockchain concept is the main supporting factor in this issue.

- *2nd point: hybrid criteria for hospital evaluation* The hospital's selection and evaluation can be achieved through several criteria. The most effective criteria in the academic literature for CVD are healthcare service packages and/or TAH. Thus, this point should be assigned if and only if the study covers the hybrid criteria.
- *3rd point: integrated evaluation and selection MCDM methods* This point reflects whether or not the study utilises integrated MCDM methods for the prioritisation outcome of the hospitals.
- *4th point: time estimation method-based GPS* To assist patients with CVD in reaching the appropriate hospital with accurate time, the framework should consider an accurate method and/or technique to handle such a process. The new technique should also integrate its process with the most interesting sensor within mHealth, which is GPS. In such a way, an accurate time can save more patient lives.
- *5th point: dataset combination criteria* On the basis of the above second point, the hybrid criteria are represented by data where the outcome of these data is a new dataset for CVD disease. Thus, this point reveals that the CVD dataset for hospital evaluation must be represented by both criteria.
- *6th point: considering all CVD emergency levels* The distinct approach that can handle selection and evaluation of hospitals must cover all health emergency levels, namely, risk, urgent, and sick.

As shown in Table 8, the comparisons are stated based on whether or not the compared works cover the issues addressed in the comparison points. Comparison results show that both benchmarks studies obtained 33.33% and covered only two points for each. The study of benchmark#1 (Albahri et al. 2019a) achieved only third and sixth points and lacked several important comparison points, such as decentralised telemedicine architecture without utilising hybrid criteria, technique for estimation time and the framework based on the dataset of hybrid criteria. In addition, the study of benchmark#2 (Albahri et al. 2019b) lacked other important comparison points. Although benchmark#2 utilised both criteria (healthcare services and TAH) and dataset, the decentralised approach was also absent in their work. Benchmark#2 considered only the risk emergency level for CVD by a unique MCDM method (i.e. AHP). On the contrary, the proposed framework contributes by presenting an all-important points research and proposes a value-adding mHeath framework.

4 Claim points

The claim points of this study can be summarised as follow:

- *Technique of GPS sensor with Haversine for distance measurement* The distance measurement between patients and hospitals is calculated by the proposed technique, and the outcome of the TAH values considers traffic jams, stopping points and transportation speed. The TAH values are estimated by real positions on the map to prepare the combination of the new dataset.
- *New hospital datasets for evaluation* The new combination dataset is achieved by using a clear guideline methodology based on real states of hospital environment for the first time. Thus, we describe a new combined dataset for three healthcare service packages and TAH values and release it for public use. In this context, the transparency of the developed new mHealth framework and associated selection processes are confirmed.
- *New mHealth framework supports offering of healthcare services* We demonstrate the enhanced healthcare services offered by decentralised telemedicine hospitals by employing the blockchain concept and provide a new powerful framework for easy mechanical decision-making selection. Thus, the continuous provision of healthcare services is not dependent on the complex issue of client–server architecture. The confidence in the offering of healthcare services through the proposed framework is also implicated in improving hospital management during disasters and emergency situations.

Table 7 Validation results of three DMs

DMs	1st group Mean ± STD	2nd group Mean ± STD	3rd group Mean ± STD	4th group Mean ± STD
DM 1	0.1011 ± 0	0.0947 ± 0	0.07867 ± 0.01781	0.09233 ± 0.00557
DM 2	0.0897 ± 0.0196	0.0854 ± 0.0196	0.0854 ± 0.0196	0.0785 ± 0.0117
DM 3	0.1282 ± 0	0.1188 ± 0.0103	0.1177 ± 0.021	0.1073 ± 0.0056

Table 8 Comparison points in the benchmarks and proposed framework

	Comparison point	Benchmark#1 (Albahri et al. 2019a)	Benchmark#2 (Albahri et al. 2019b)	Proposed
1	Decentralised telemedicine architecture	χ	χ	√
2	Hybrid criteria for hospital evaluation	χ	√	√
3	Integrated evaluation and selection of MCDM methods	√	χ	√
4	Estimation time method-based GPS	χ	χ	√
5	Dataset combination criteria	χ	√	√
6	Considering all CVD emergency levels	√	χ	√
Total score		33.33%	33.33%	100%
Finding difference		66.67%	66.67%	

5 Conclusion

Hospital evaluation and selection framework for patients with CVD and their emergency levels are presented in this study. Finding and selecting eligible hospitals for patients with CVD under different emergency levels can be challenging within telemedicine hospitals. In these contexts, analysing and assessing several gaps are fulfilled and solved through the development framework, and the applicability of the hospital evaluation and selection is assessed by comparing the recent literature. Implication for practice the presented framework those health sectors and policymakers are capable to recognise the evaluation benefits of decentralised hospitals that are remotely and able to move forwards a fully automated mHealth application. The results are validated objectively in this research. For evaluation, six main points and checklist benchmarking are provided to demonstrate the performance of the proposed health recommender mHealth framework for hospital evaluation and selection. To gain deeper insights into the investigated field, the availability of the presented mHealth would help in better management of decentralised telemedicine hospitals, providing timely services and treatment for patients with CVD and minimising the chances of error. For future direction, another case study (i.e. multi chronic disease) can be served through the presented framework. After the selection process is achieved and decision has been set, diverse issues could occur. For example, the offered services within some hospitals could be changed, which is normal in a hospital workflow. Another issue, the health emergency level of patients may change from one level to another or vice versa. Thus, after selected a hospital for the current emergency situation of patients, recycling the decision approach based on a new emergency level is highly recommended to reconsider another appropriate hospital with an accurate evaluation and selection process. Different MCDM techniques can be further investigated and compared.

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